

MASTER - A New Instrument for Hyperspectral Analysis from the Visible to Thermal Infrared

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Background

- The gradual decommissioning and retirement of the TIMS instrument left a gap in the solid earth and natural hazards TIR airborne remote sensing capabilities.
- The ASTER science team needed an airborne instrument for algorithm development and validation.
- MASTER was developed as a follow-up to the MAS instrument design with enhanced electronic subsystems, a variable scan-speed motor and hard drive data recorders.

Primary Mission

Collect ASTER-like and MODIS-like land datasets to support the validation of the ASTER and MODIS geophysical retrieval algorithms.

- Collect these datasets at a higher resolution than the spaceborne datasets to permit scaling studies and comparisons with in-situ measurements.
- Underfly the EOS-AM1 ASTER and MODIS sensors to provide an additional radiometric calibration to assist with in-flight instrument performance characterization.

Secondary Mission

- Provide both a backup instrument and interchangeable modules for the current MODIS Airborne Simulator, which is committed to a program of atmospheric, oceanic and land measurements.
- Provide a wider spectral and dynamic range alternative to the use of the Thematic Mapper Simulator (TMS) and the Thermal Infrared Multispectral Scanner (TIMS) airborne scanners.

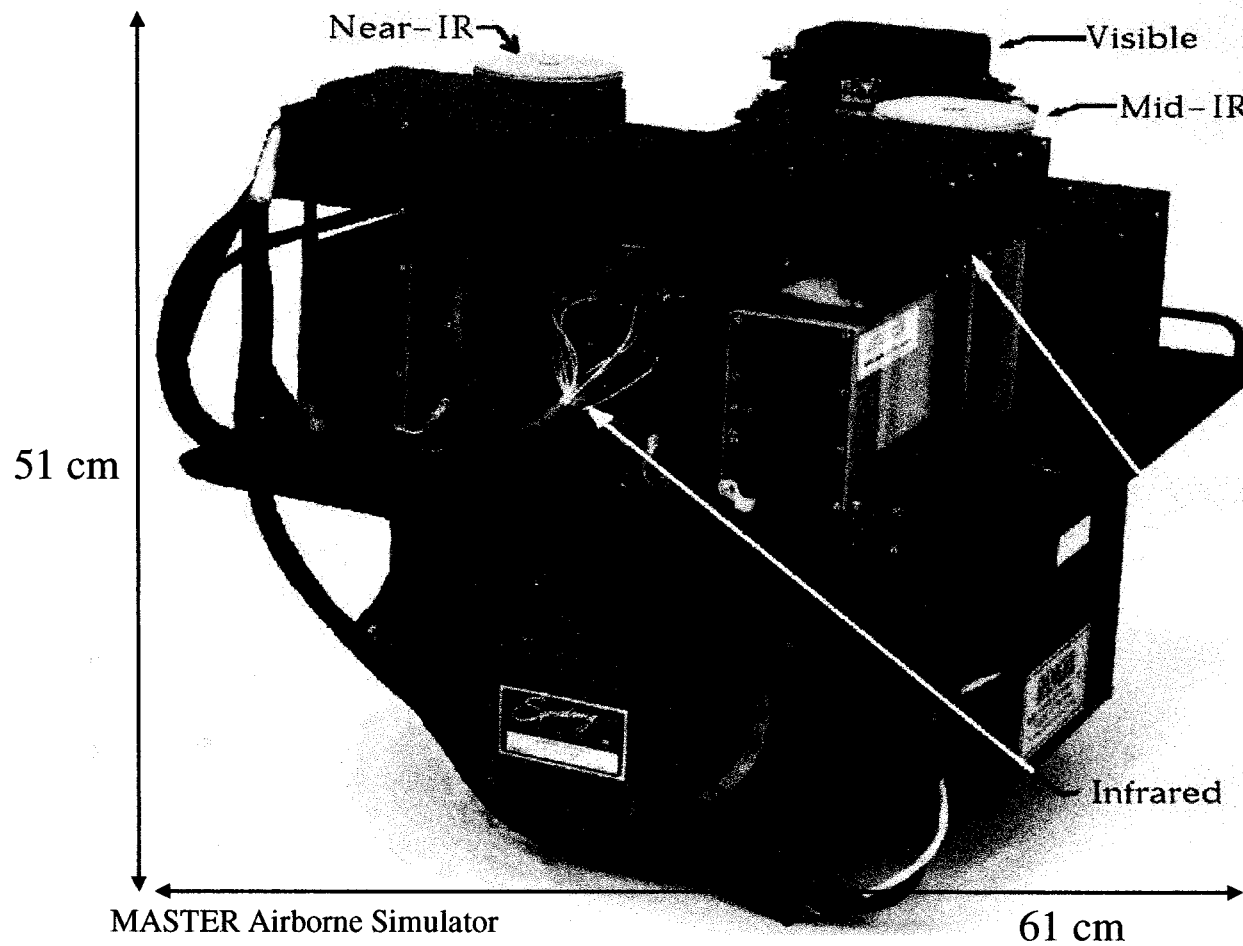
Status and Future Modifications

- Instrument declared operational on B200 in December 1998.
- Addition of linear variable filter to reduce noise in mid-infrared channels.
- Addition of attitude sensor to allow geo-correction of MASTER data.
- Integration and validation of MASTER on the DC-8.
- Integration and validation of MASTER on the ER-2.

Instrument Characteristics

Wavelength range	0.4-13 micrometers
Number of channels	50
Number of pixels	716
Instantaneous Field of View	2.5 milliradians
Total Field of View	85.92 degrees
Platforms	Department of Energy KingAir Beachcraft B200 NASA ER-2 NASA DC8
Pixel size DC-8	10-30 m
Pixel size ER-2	50 m
Pixel size B200	5-20 m
ER-2 Range (without refueling)	3700 statute miles
B200 Range (without refueling)	700 statute miles
DC-8 Range (without refueling)	5400 nautical miles
Scan speeds	6.25/12.5/25 rps
Products	Radiance at sensor (Level 1B)
Calibration VIS-SWIR	Laboratory Integrating Sphere
Calibration MIR-TIR	2 On-board Blackbodies
Data Format	Hierarchical Data Format (HDF)
Digitization	16-bit

MASTER Instrument



MASTER Calibration

- MASTER Spectral Response Functions (SRFs)
 - **All 50 channels measured before and after every deployment with monochromator and/or FTIR**
- NIST traceable radiometric source
 - **Pre and post deployment laboratory calibrations of bands 1-25 over 30 inch sphere at multiple light levels.**
- Extended Area Blackbody (EABB)
- Blackbody characterization
- Environmental Cold Chamber
- Field hemisphere
- Ground validation

Data Processing Status

- *MASTER* Level-0 (raw) data are recorded on removable hard disks. Back-up copies of the flight data are made to DLT tape. Raw data is NOT distributed.
- Analyst performs detailed evaluation of instrument performance and reports on flight success and readiness for next mission.
- A level-0 quicklook product can be generated and hard-copy produced if all data analysis requirements are met.
- Level-0 data is shipped to the Airborne Sensor Facility at NASA Ames Research Center for level-1b processing and generation of HDF output data.
- Level-1b data is distributed to US principal investigator or foreign point of contact. Archive copy of *MASTER* data is also sent to the EDC (land processes) DAAC

Level-1B Data Processing

The level-1b data product contains radiometrically calibrated and geo-located image data for all bands. Straight and level flight tracks over target sites are archived.

4 Primary inputs into level-1b processing

- 1. Raw data**
- 2. Calibration (spectral and radiometric)**
- 3. Navigation Data**
- 4. Flight descriptors**

MASTER Level-1b Inputs, Raw data

- Recorded as 16-bit, unsigned integer in raw SCSI onto removable hard disks.
- 52 bands of data, with housekeeping and engineering data.
- Dynamic brightness offsets during acquisition tracks DC drift of detector output.



MASTER Level-0 data
Band 48 (11.3 um)

MASTER Level-1b inputs, Calibration information

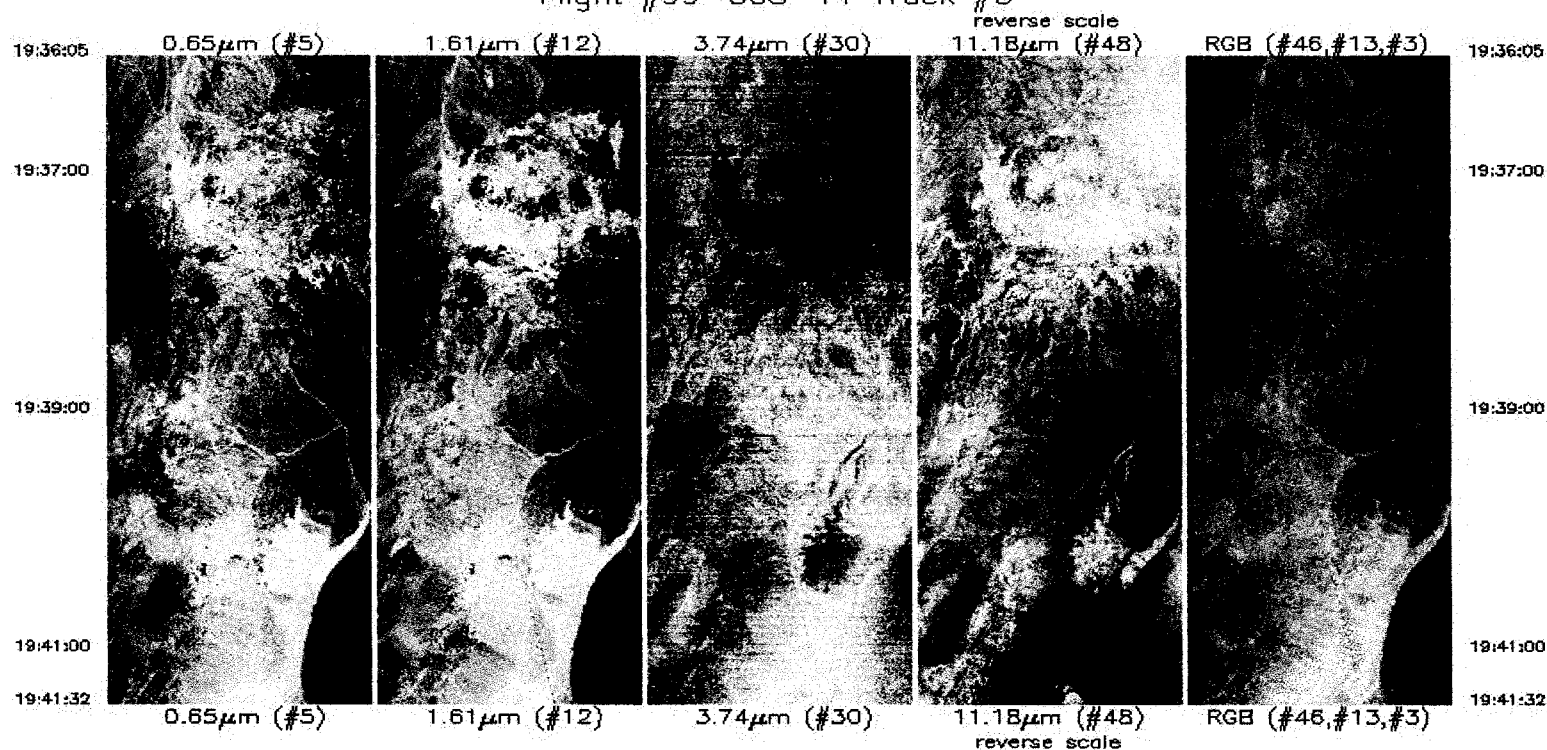
- Radiometric calibration slopes for VIS/SWIR
 - **based upon lab measurements over sphere**
- Spectral Response Functions
 - **center, peak, half power points and FWHM determined**
 - **solar irradiance function calculated**
- Blackbody paint characterization
 - **emissivity calculated**
- Instrument operating temperature

MASTER Level-1b Inputs, Navigation Data

- Navigation data collected from multiple sources.
- Navigation data is filtered and re-sampled for every scan line of MASTER data.
- Latitude and Longitude is given for every pixel.
- Aircraft position, heading, pitch and altitude are stored as unique scientific data sets in the level-1b HDF file.

HDF Quicklook Browse Image

ASTER/MODIS Airborne Simulator Browse Imagery
SW Sites, Jun99 Campaign - 9 June 1999
Cuprite, NV
Flight #99-005-11 Track #6



Aircraft Heading = 190.9°
Solar Zenith = 15.1°
GPS Altitude = 9648. m (MSL)

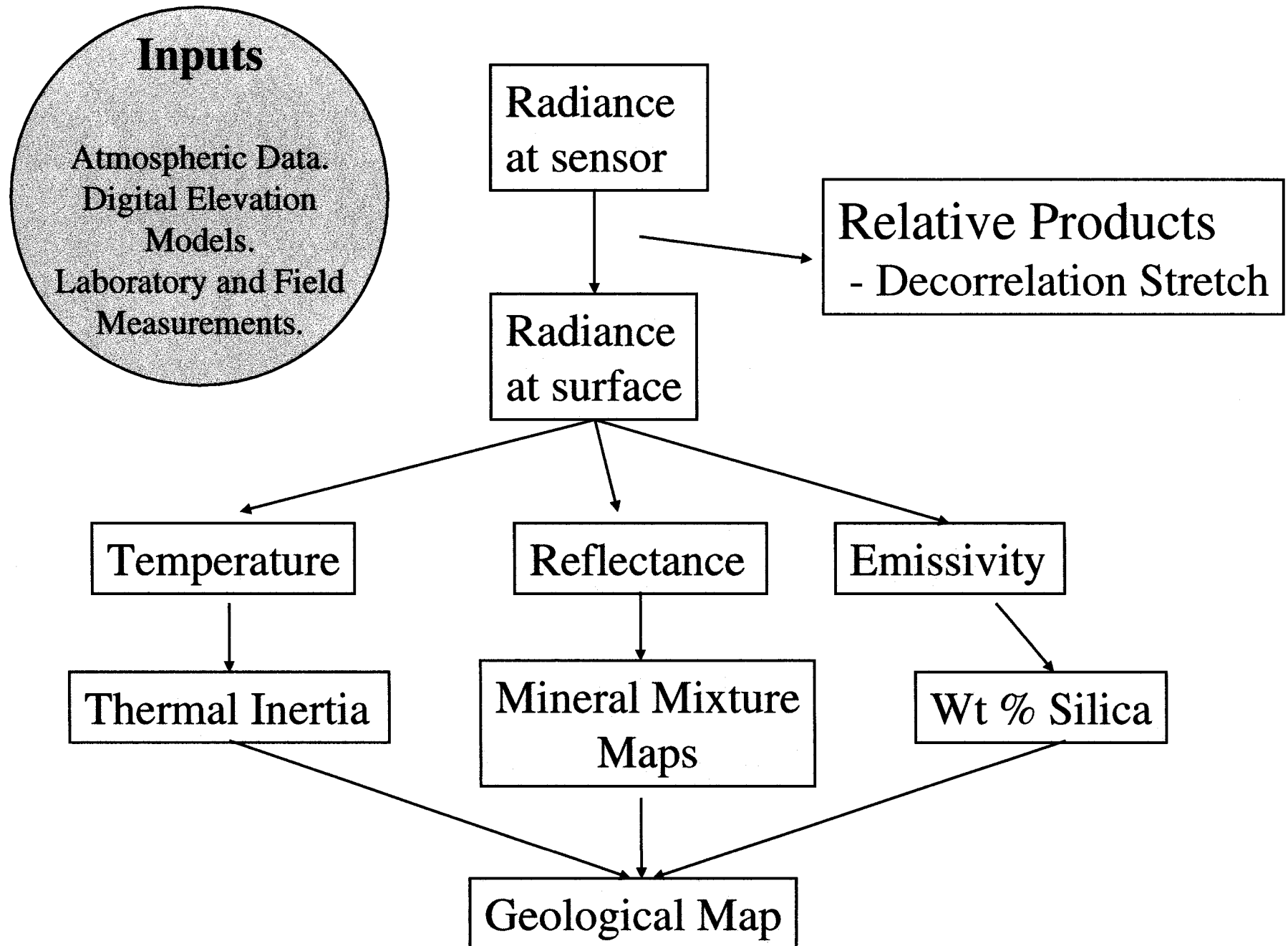
MASTER Data HDF Format

The Hierarchical Data Format (HDF) has been selected by the EOSDIS Project as the format of choice for standard product distribution. HDF consists of a directory structure and a collection of data objects or Scientific Data Sets (SDS).

- MASTER HDF image data is stored as integer but unpacked to real (floating point) data in radiance units.
- MASTER HDF currently consists of 37 Global attributes and 44 scientific data sets
 - 15 SDS's for calibration information
 - 12 SDS's for navigation information
 - 27 SDS's for engineering information
- Software is available to directly import MASTER HDF.
- Unpacking code available to strip image data out of HDF format.

Resources for MASTER and HDF Information

- MASTER web page
 - <http://masterweb.jpl.nasa.gov/>
- MAS web page
 - <http://ltpwww.gsfc.nasa.gov/MODIS/MAS/>
- Airborne Sensor Facility web page
 - <http://asapdata.arc.nasa.gov>
- HDF information
 - <http://eosweb.larc.nasa.gov/HBDOCS/hdf.html>
 - http://daac.gsfc.nasa.gov/REFERENCE_DOCS/HDF/gdaac_hdf.html

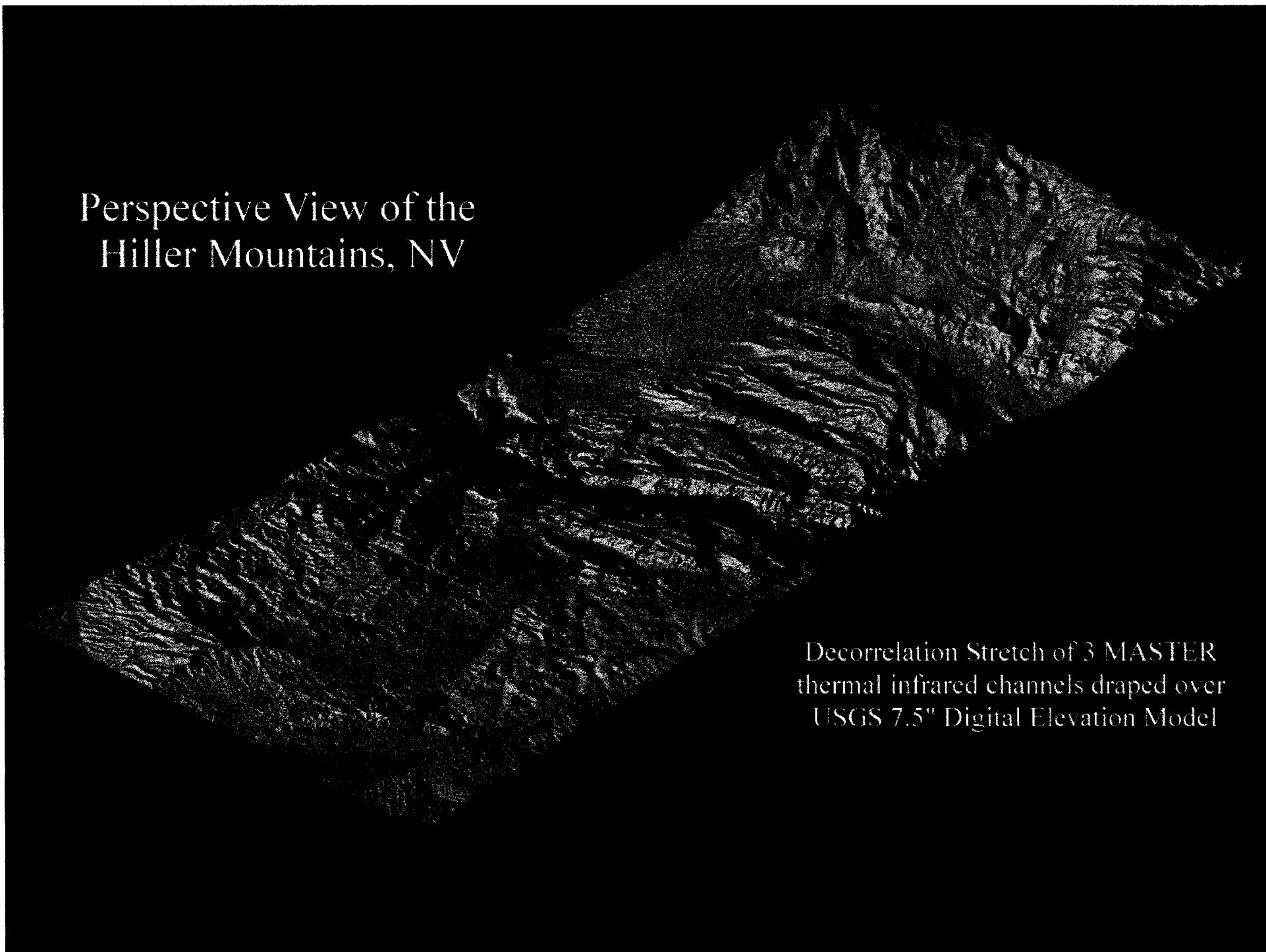


Decorrelation Stretch of MASTER TIR Channels 7 (10.6 μm) 4 (9.1 μm) and 2 (8.2 μm) displayed in RGB. Virgin Mountains, CA

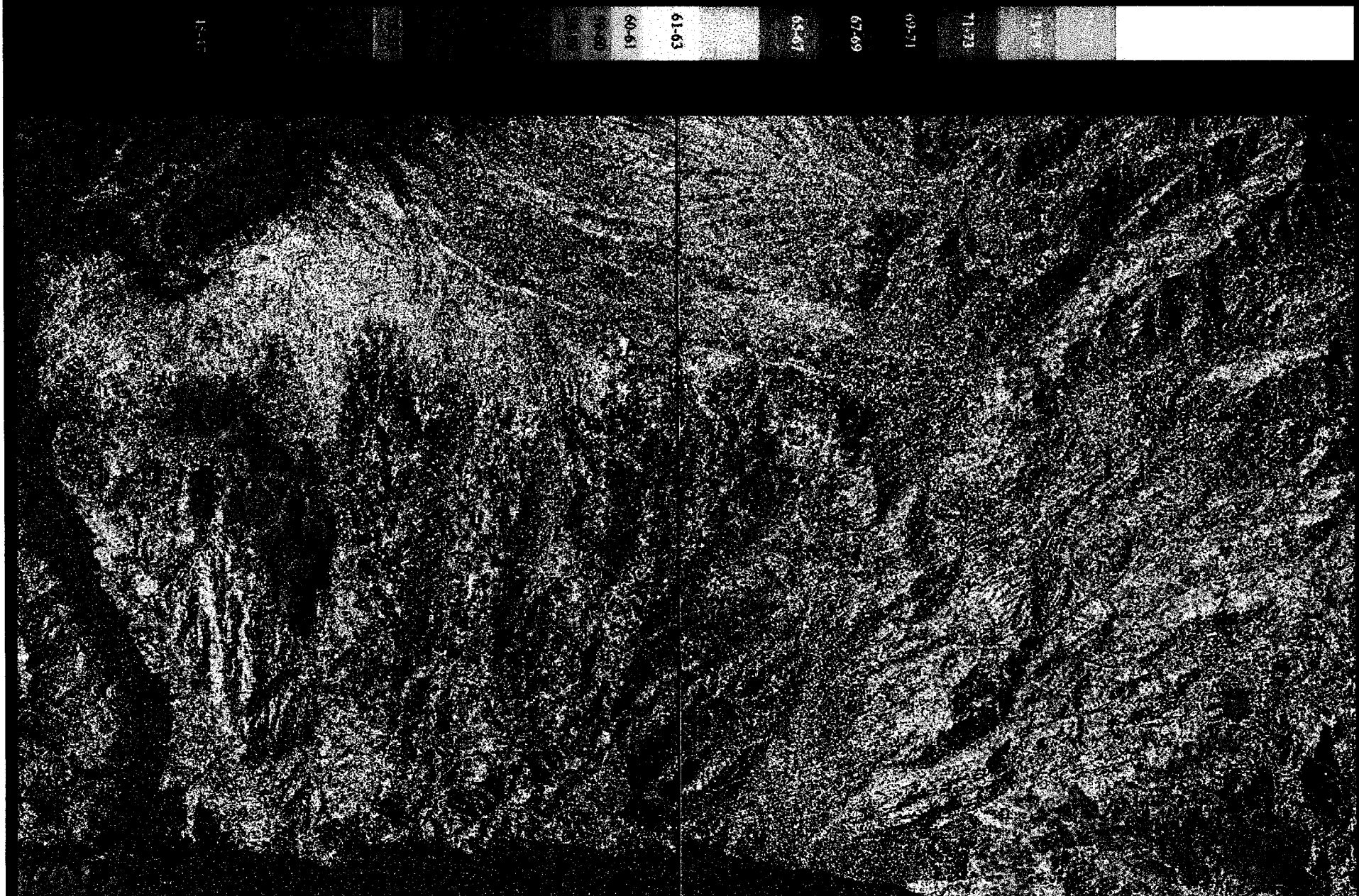


Perspective View of the
Hiller Mountains, NV

Decorrelation Stretch of 3 MASTER
thermal infrared channels draped over
USGS 7.5" Digital Elevation Model



Wt % Silica Map Derived from MASTER Emissivity Data



MASTER B200 Validation Experiment

Approach

- MASTER data acquired from Ivanpah Playa, CA and Lake Mead NV on December 12th 1998.
- Field teams deployed from the University of Arizona and the Jet Propulsion Laboratory to measure surface and atmospheric properties.
- Field radiance propagated through atmosphere to allow comparison of predicted radiance with measured radiance.

MASTER Validation - continued.

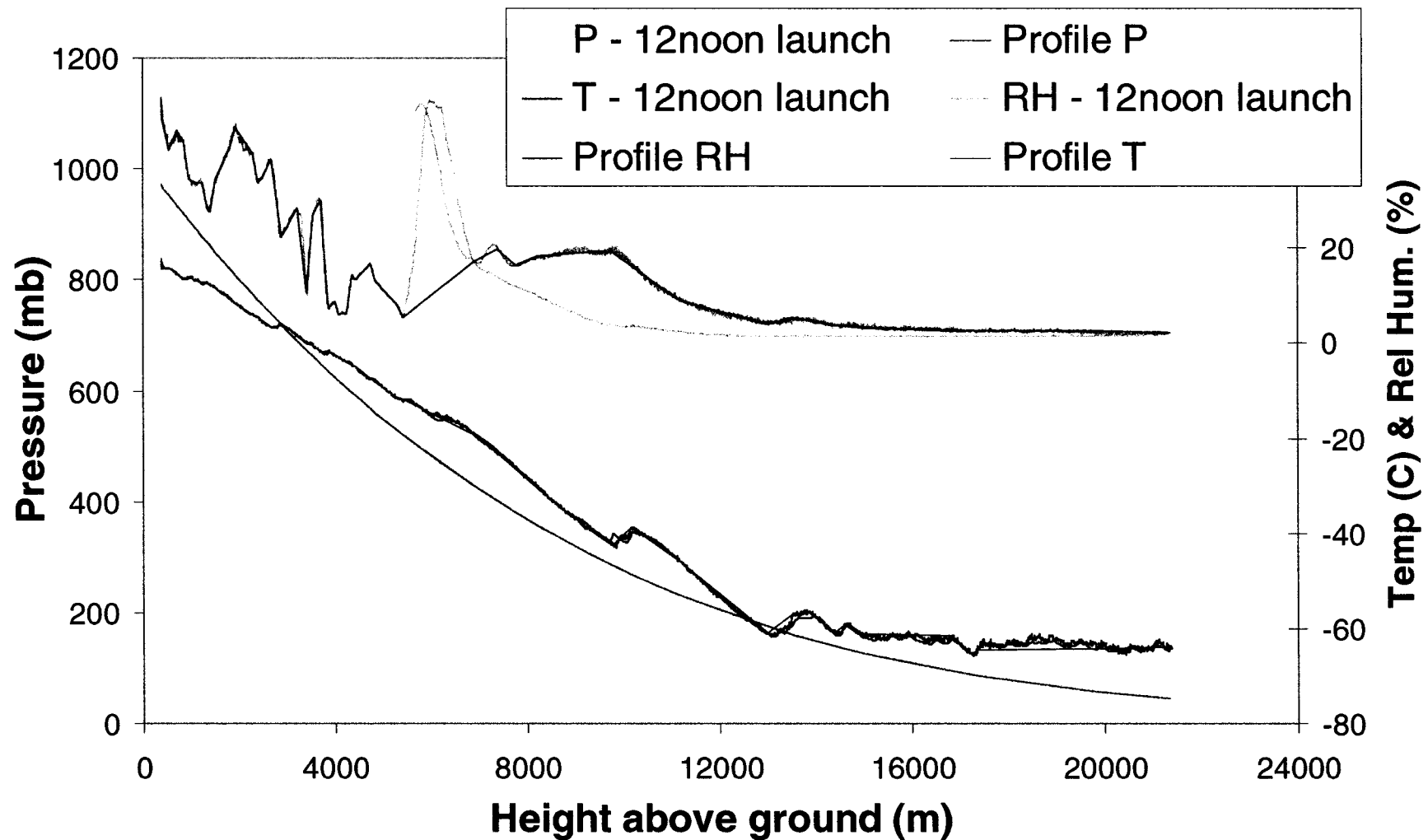
- **Instrumentation**

- Atmospheric sounders.
- Reagan sun photometers.
- Field spectrometers.
- Self calibrating radiometers.
- Bulk temperature loggers.
- Differential GPS receivers.

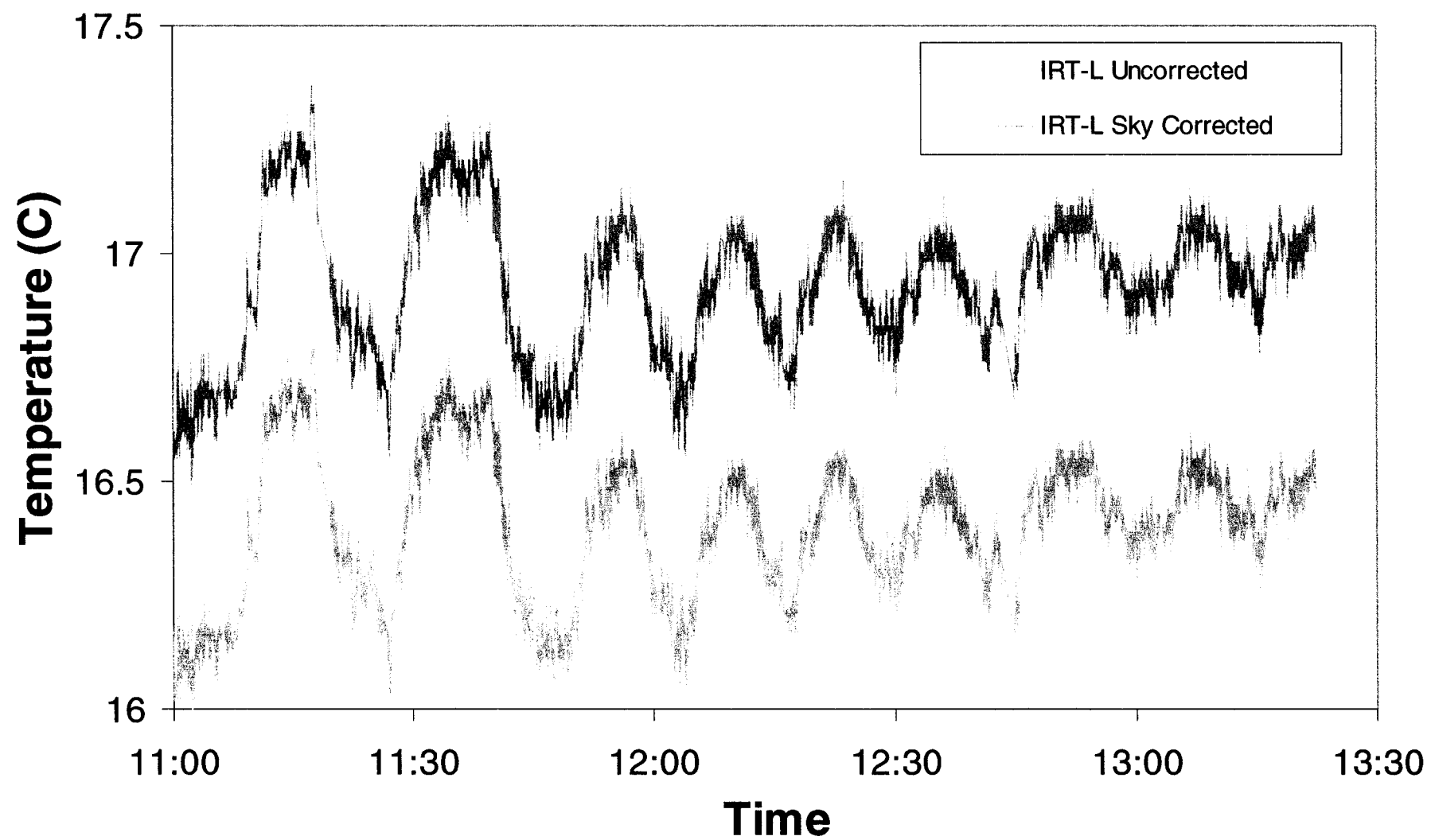
MASTER Radiance at Sensor - Channel 44 (9.1 μm)



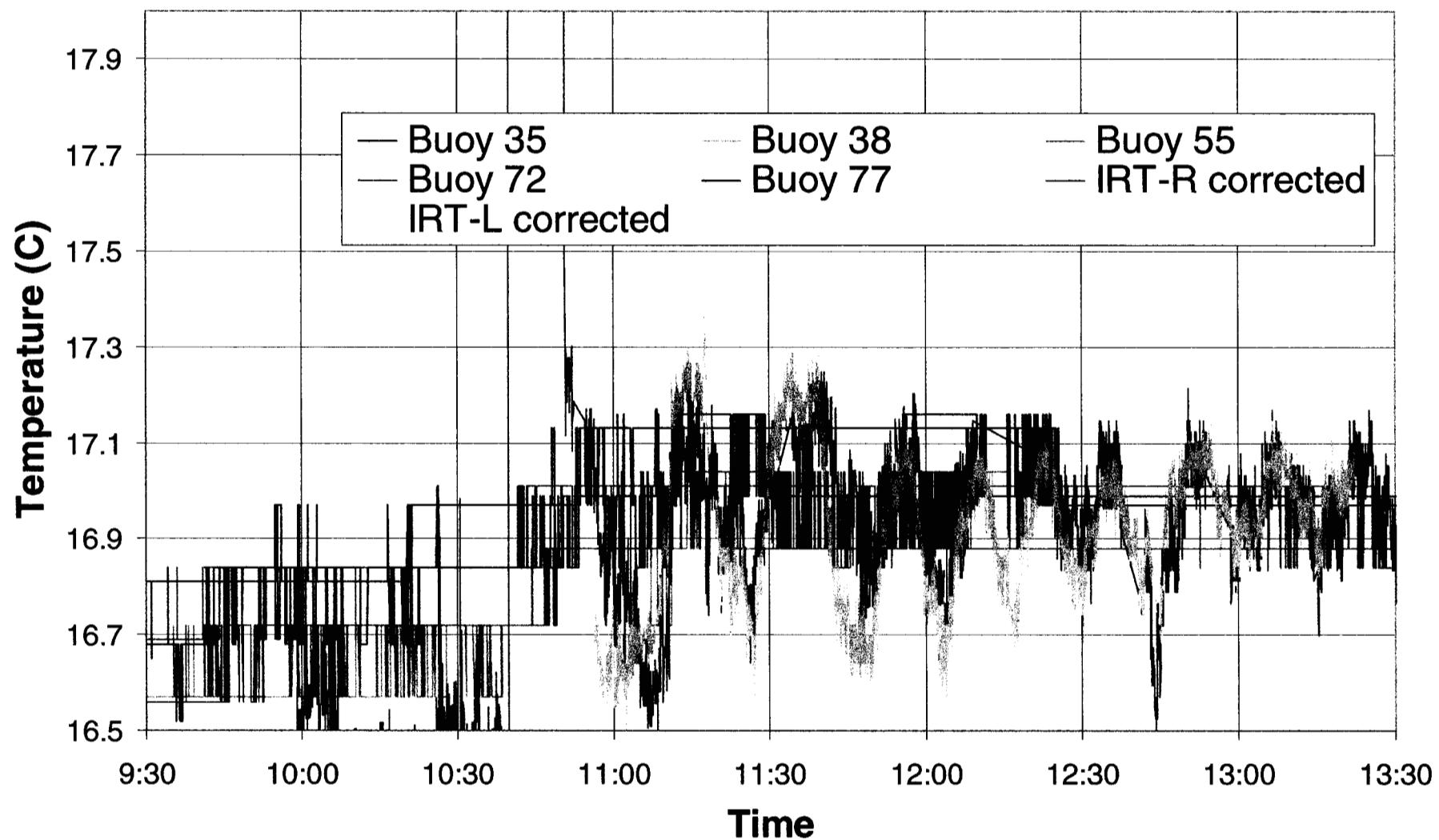
12-2-98 Airsonde Data & Derived Profile



12-2-98 Radiometer Data



12-2-98 Buoy and Radiometers Data



Visible - Shortwave Infrared Validation Results

Channel Number	Center Wave-length	Radiances (W/m2 um sr)								
		Low Altitude			Medium Altitude			High Altitude		
		Predict	MASTER	% Difference	Predict	MASTER	% Difference	Predict	MASTER	% Difference
1	0.457	58.288	58.400	-0.192	58.597	57.100	2.554	60.256	57.200	5.072
2	0.498	66.493	68.500	-3.018	64.766	64.900	-0.207	64.984	63.700	1.976
3	0.540	79.552	81.300	-2.197	75.832	75.500	0.437	74.765	72.500	3.030
4	0.581	90.558	91.500	-1.040	85.136	83.800	1.569	83.082	79.700	4.071
5	0.660	90.166	92.000	-2.034	84.044	84.100	-0.067	81.487	79.200	2.807
6	0.711	82.338	83.800	-1.775	75.329	76.300	-1.290	72.522	71.500	1.409
7	0.750	76.452	79.000	-3.333	69.786	71.900	-3.030	67.017	67.200	-0.273
8	0.800	73.746	77.600	-5.225	68.028	70.700	-3.929	65.678	66.000	-0.490
9	0.866	64.052	70.300	-9.755	59.695	64.500	-8.049	57.838	60.100	-3.911
10	0.906	48.586	53.000	-9.084	43.273	48.000	-10.923	41.310	44.400	-7.481
11	0.945	28.558	34.030	-19.159	23.492	30.270	-28.853	21.885	27.470	-25.523
12	1.609	19.857	21.060	-6.061	18.348	19.390	-5.681	17.633	18.150	-2.933
13	1.665	18.139	19.450	-7.226	16.808	17.920	-6.615	16.194	16.850	-4.049
14	1.720	15.135	16.390	-8.290	13.855	15.060	-8.699	13.321	14.240	-6.899
15	1.775	8.361	9.440	-12.911	7.190	8.580	-19.332	6.795	8.090	-19.058
16	1.828	0.496	1.500	-202.358	0.350	1.400	-300.114	0.313	1.200	-283.264
17	1.875	0.035	0.730	-1973.864	0.030	0.690	-2238.983	0.028	0.570	-1943.011
18	1.924	0.299	1.100	-267.401	0.180	0.970	-440.390	0.147	0.790	-436.320
19	1.981	3.545	3.800	-7.196	2.687	3.320	-23.581	2.390	3.020	-26.365
20	2.081	6.923	7.140	-3.134	5.975	6.410	-7.288	5.541	5.950	-7.391
21	2.160	6.673	7.210	-8.055	6.143	6.600	-7.436	5.913	6.250	-5.698
22	2.211	5.686	6.340	-11.506	5.213	5.780	-10.875	4.999	5.430	-8.626
23	2.258	5.277	5.600	-6.127	4.798	5.090	-6.088	4.554	4.780	-4.958
24	2.328	4.021	3.990	0.781	3.535	3.580	-1.267	3.296	3.360	-1.936
25	2.394	2.455	2.520	-2.643	2.045	2.250	-10.041	1.885	2.100	-11.418

Thermal Infrared Validation Results

Channel Number	Center Wave-length	Radiances (W/m2 um sr)								
		Low Altitude			Medium Altitude			High Altitude		
		Predict	MASTER	% Difference	Predict	MASTER	% Difference	Predict	MASTER	% Difference
41	7.760	6.193	6.182	0.187	5.583	5.547	-1.040	5.101	4.881	4.325
42	8.168	7.163	7.155	0.117	6.967	6.899	-0.050	6.844	6.763	1.186
43	8.632	7.681	7.701	-0.258	7.613	7.563	-0.226	7.588	7.559	0.379
44	9.094	7.975	7.990	-0.181	7.930	7.900	-0.251	7.916	7.874	0.520
45	9.700	8.175	8.211	-0.441	8.102	8.039	0.027	8.023	8.002	0.262
46	10.116	8.223	8.253	-0.362	8.199	8.165	-0.017	8.189	8.151	0.462
47	10.633	8.156	8.196	-0.483	8.133	8.107	-0.574	8.130	8.092	0.470
48	11.329	7.931	7.952	-0.255	7.911	7.879	-0.108	7.915	7.880	0.447
49	12.117	7.525	7.541	-0.217	7.493	7.458	-1.422	7.490	7.440	0.670
50	12.878	7.040	7.011	0.408	6.956	6.854	-1.784	6.910	6.871	0.556